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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Under ONR contract No. N00014-80-C-0957, an intense and efficient source for blue-green laser useful for the space-based satellite laser applications, underwater strategic communication, and measurement of ocean bottom profile is being developed. The source in use, the hypocycloidal pinch plasma (HCP), and the dense plasma focus (DPF) can produce intense uv photons (200-400nm) which

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match the absorption spectra of both near uv and blue-green dye lasers (300-400nm).

As a result of optimization of the DPF light at 355nm, the blue-green dye (LD490) laser output exceeding 4mJ was obtained at the best cavity tunning of the laser system. With the HCP pumped system a significant enhancement of the blue-green laser outputs with dye LD490 and coumarin 503 has been achieved through the spectrum conversion of the pumping light by mixing a converter dye BBQ. The maximum increase of laser output with the dye mixture of LD490+BBQ and coumarin 503+BBQ was greater than 80%. In addition, the untuned near uv lasers were also obtained. The near uv laser output energy of P-terphenyl dye was 0.5mJ at λ_c=337nm with the bandwidth of 3nm for the pulse duration of 0.2us. Another near uv laser output energy obtained with BBQ dye was 25 mJ at λ_c=383nm with the bandwidth of 3nm for the pulse duration of 0.2μs.

Annual Summary Report

of

Intense Excitation Source of Blue-Green Laser

Under

(ONR Grant No. N00014-80-C-0957)

Period Covered

Oct 1, 1985 - Sept 30, 1986

Principal Investigator

Kwang S. Han

Oct 6, 1986

Hampton University

Hampton, Virginia 23668

Annual Summary Report

of

An Intense Excitation Source of Blue-Green Laser

Under ONR Contract No. N00014-80-C-0957, an intense and efficient excitation source for blue-green and near uv lasers is being developed. The source in use, the dense-plasma focus (DPF) and the hypocycloidal-pinch plasma (HCP) can produce intense uv photons (200-400nm) which match the absorption bands of near uv (300-400nm) dye lasers.

During the current project period, our research efforts have been directed to reproduce the well-stabilzed plasma focus from the DPF device, and optimize the DPF light near 355nm as a function of argon or argon/deuterium fill gas. After the optimization of the DPF emission at 350nm, the blue-green dye (LD490) laser was optimized by cavity tuning. Also the excitation of near uv dye (LD390) laser has also been attemped. Experimental results showed that the optimum fill gas pressure for the DPF emission at 350nm was 0.5 Torr of 10% argon and 90% deuterium mixture. The blue-green dye (LD490) laser output exceeded 4mJ at the best cavity tuning of the laser system. This corresponds to 8J/liter laser energy extraction. On the other hand, the pumping of near uv dye (LD390) laser was not successful due to the high loss of the pump-band uv in the optical coupling materials between the DPF source and the laser cavity, and the limitation of the high voltage power supply, which limited the pumping power below the threshold of the LD390 dye laser.

With the HCP pumped system, a significant ehancement of the blue-green laser outputs of the dyes LD490 and coumarin 503 has been achieved through spectrum conversion of pumping light by mixing a converter dye BBQ. The

maximum increase of the laser output with the dye mixtures of LD490+BBQ and coumarin 503+BBQ was greater than 80%. The enhancement is mainly effected by the high irradiance in the uv bands of the HCP pumping light. This enhancement will definitely be helpful in obtaining high power blue-green laser output (>1MW) with the existing blue-green laser systems. In addition, the untuned near uv laser output was also obtained with P-terphenyl dye. The laser output energy was 0.5mJ at λ_c=337nm with a band of 3nm for a pulse duration of 0.2μs. Another near uv laser output energy with BBQ dye was 25mJ with the bandwidth of 3nm for the pulse duration of 0.2μs.

We propose here a renewal for continued efforts toward our goal of developing an intense uv source for blue-green lasers by further improvement of the HCP pumped systems and initiating a study on a new and novel light source which is called a hard-core flashlamp. As shown in figure 1, the hard-core flashlamp is equivalent to an array of inverse-pinches. The investigations to be made for realizing high optical efficiency for the hard-core flashlamp laser system are: (1) the current sheets from the surface discharge which disperse the plasmas radially away from the axis, instead of pinching (See figure 1), (2) effects of high-Z doping such as Ar and Xe which will result in a radiatively-cooled high-density ($n_e \sim 10^{24} m^{-3}$) plasma at relatively low temperature ($10^4 \sim 10^5$K) suitable for pumping uv lasers.. (3) coupling efficiency of the cylindrical mirror (uv reflectivity enhanced) (See Fig. 1) used for the optical coupling of the source and the laser tube located on the conjugate focal lines. The dye lasants to be pumped for evaluation of the new pump source are DMT, PTP, BPBD, and TMQ, all tunable in the uv band. Attempt will be made to optimize the emission spectrum of the pump source for each of these lasants. Advantages expected of this system over the conventional

flashlamp are (1) a high electrical-to-light conversion efficiency. The flashlamp is operated by surface flashovers which produce an uv-rich spectrum. (2) a fast risetime. The coaxial current path minimizes the circuit inductance. (3) spectrum selectability, and (4) compactness. The inverse pinch geometry gives a high input power density per unit length.

For further enhancement of the HCP uv emission, XeCl doping will be attempted. Since XeCl spectrum from discharges in Xe/HCl or Xe/Cl_2 mixture shows the significant increase of the flouorescence yield near 310nm[1], the high uv irradiation from the HCP pumping light is expected and will make the additional enhancement in pumping near uv dye lasers and the blue-green laser of dye mixture LD490+BBQ or coumarin503+BBQ. Therefore, the study of the HCP emission as a function of the Xe/HCl or $XeCl_2$ doped gas is proposed for the improvement of the HCP pumped system.

II. RECENT PROGRESS OF THE PROJECT

As mentioned in the report annual summary (dated 10/15/85), the uv emission from the DPF device have been measured as a function of fill pressure of 10% argon and 90% deuterium and the different combination of argon/deuterium at three different fill pressures at fixed wavelength of 350nm. Figure 2 and 3 show that the optimum fill pressure of the DPF device was 0.5 Torr for 10% argon and 90% deuterium. In particular, the peak irradiance of the DPF emission at 350nm was about two times stronger at the optimum fill pressure than at a fill pressure of 1 Torr. However, at present time, excitation of near uv laser with LD390 dye is not successful due to the high loss in the optical coupling materials between the pumping source and laser cavity, and the

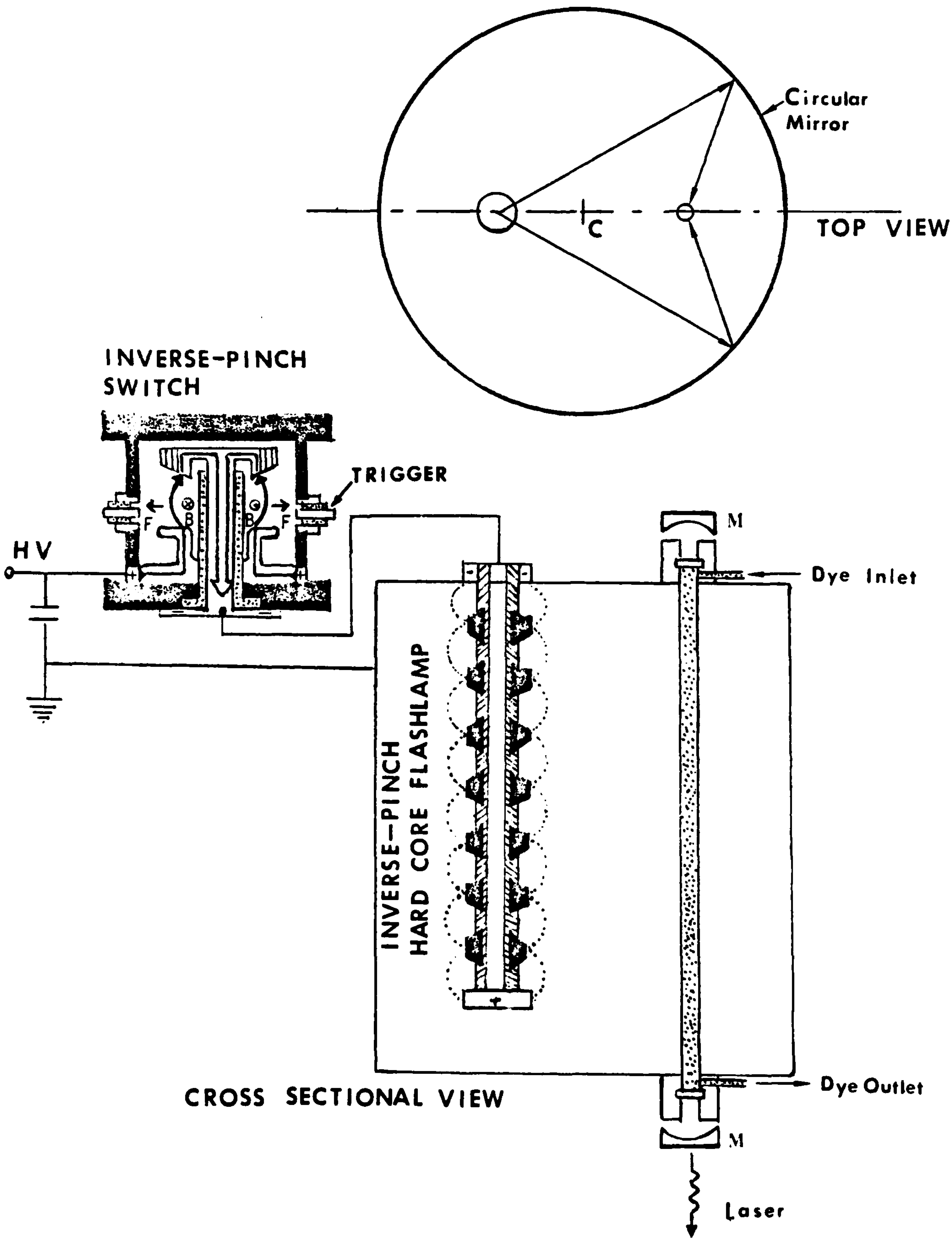
limitation of the high voltage supply, which limits the pump power below the threshold of LD390 dye laser. On the other hand the untuned blue-green laser was excited easily and its energy exceeded 4mJ as measured with an energy meter. This corresponds to 8J/liter laser energy extraction. As shown in figure 4 and 5, the optimum operating conditions of the DPF device for blue-green laser pumping were argon pressure 0.3 Torr, dye concentration 6×10^{-4} mol/liter, and 10% output coupling mirror. The laser output 4mJ corresponds to the extraction energy density 8J/liter which is much higher than the typical flashlamp-pumped dye laser. The details of experimental results are reported at the 1985 Conference of International IEEE Plasma Science.

In a separate experiment with the HCP array, the study of enhancing the blue-green dye laser output of LD490 and coumarin 503 dye (EXCITON) through the spectrum conversion of the HCP pumping light has been made successfully with a converter dye BBQ (EXCITON). Figure 6 and 7 shows that the maximum increase of laser output at the dye mixture of LD490+BBQ or coumarin 503+BBQ was greater than 80%. The estimated enhancement calculated by a simple spectrum conversion model agrees well with the experimental results. The enhancement is mainly due to the good match of the fluorescence band of the converter dye with the absorption band of the laser dye, and the lack of the overlap of the fluorescence band of the laser dyes with the triplet-triplet absorption band of the converter dye used. The details of the experimental results are published in the Journal of Applied Physics (Issue of Nov.15, 1986).

Another separate experiment of lasing near uv dye laser of P-terphenyl (λ_c=337nm) and BBQ (λ_c=383nm) with the HCP pumping source have been conducted. After optimizing the light source for pumping the near uv dye laser with

P-terphenyl, an untuned laser output of 0.5mJ at λ_c=337nm with a bandwidth of 3nm and a pulse duration of 0.2μs was obtained. Figure 8a,8b, 8d show laser output energy as a function of the dye concentration, the argon fill gas pressure, and the input energy. Figure 8c shows the rise time of the HCP pumping light as a function of the argon pressure. Another near uv laser output energy of BBQ dye was 25mJ at λ_c=383nm with a bandwidth of 3nm for the pulse duration of 0.2μs. Figure 9a, 9b, and 9c show laser output energy as a fucntion of the dye concentration, the argon fill pressure, and the input energy. Figure 9d shows the rise time of the HCP pumping light as a function of the argon fill pressure. It has been noted that the uv dye laser output with the HCP light is much higher than that with the conventional flashlamp pumping. The details of the experimental results will be reported in Lasers' 86 Conference.

Fig. 1 A hard-core flashlamp laser system.



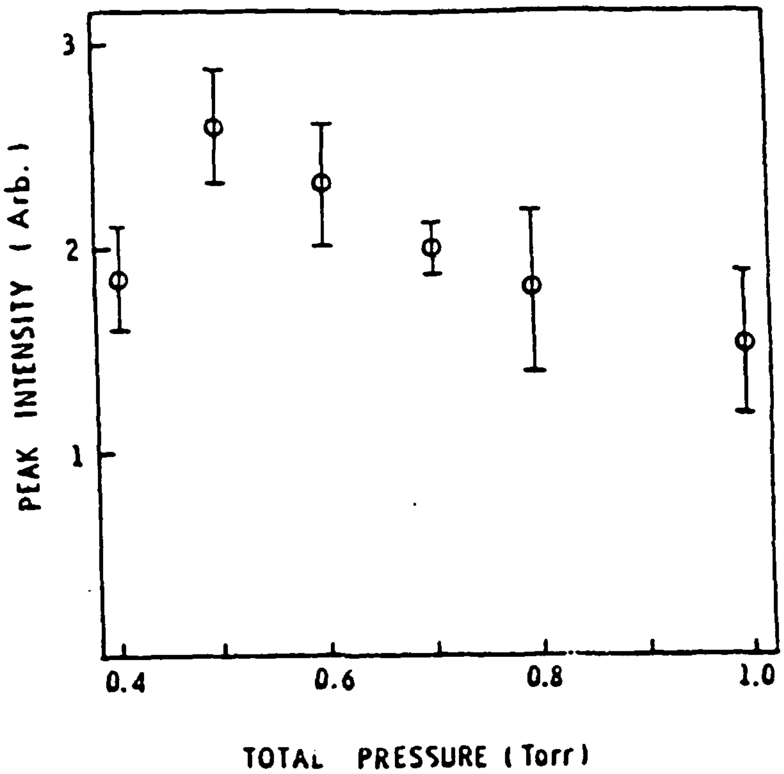


Fig. 2 Peak intensity of the DPF light at 350nm as a function of total fill gas pressure with 10% argon and 90% deuterium.

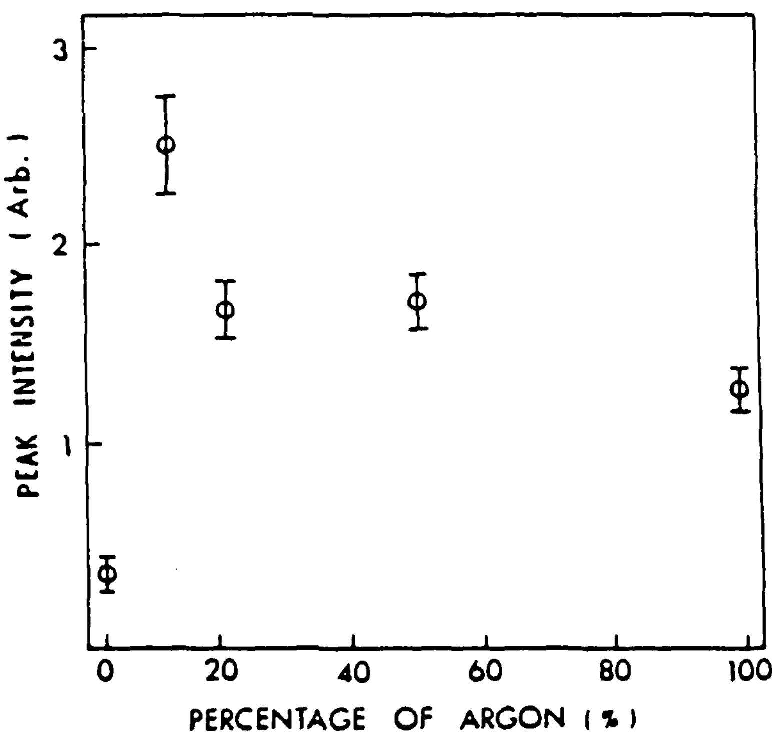


Fig. 3 Peak intensity of the DPF light at 350nm as a function of percentage of argon in 0.5Torr of total fill gas pressure of argon and deuterium.

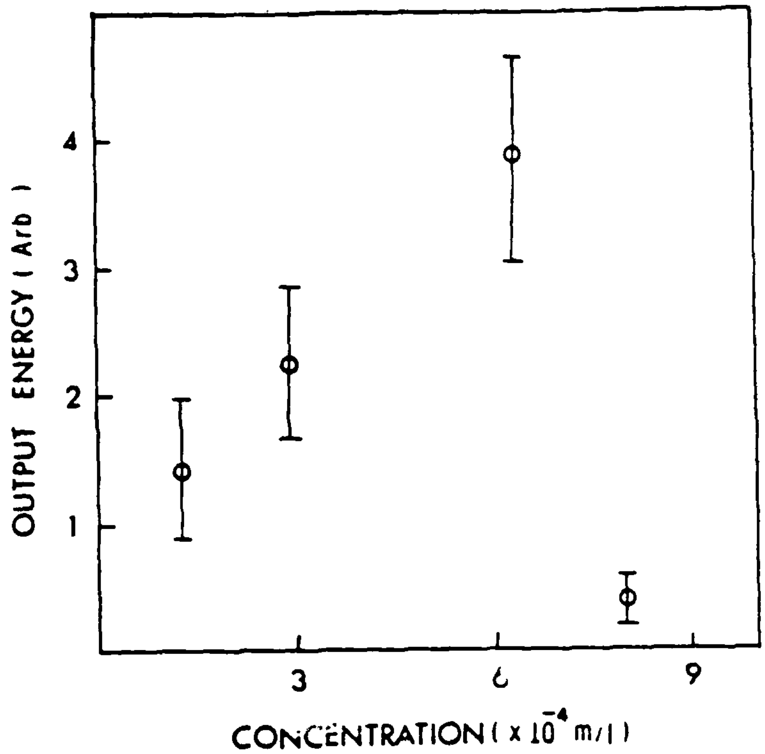


Fig. 4 Blue-green laser output of LD 490 dye with the HCP pumping light as a function of dye concentration.

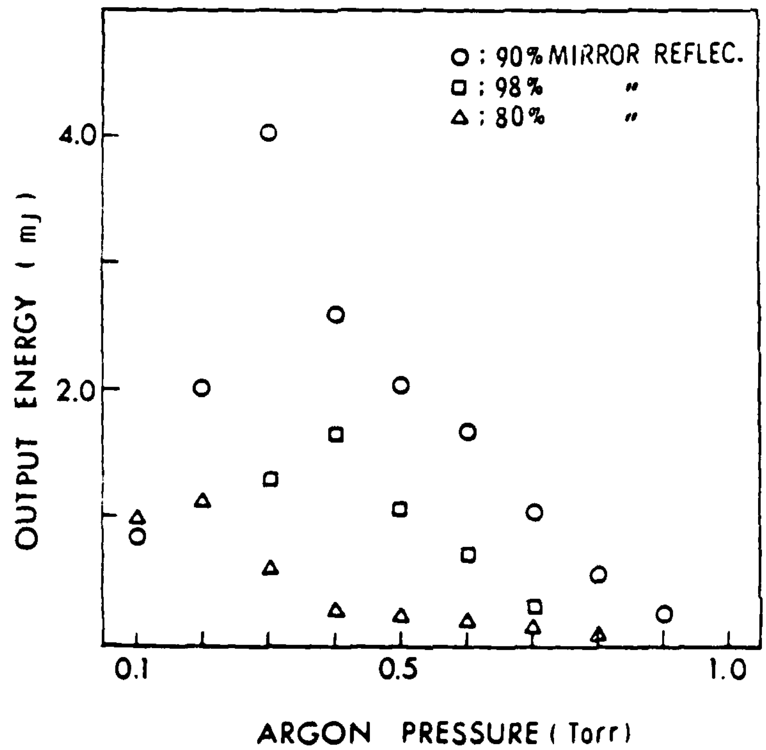


Fig. 5 Blue-green laser output of LD490 dye with the HCP pumping light as a function of output coupling mirror.

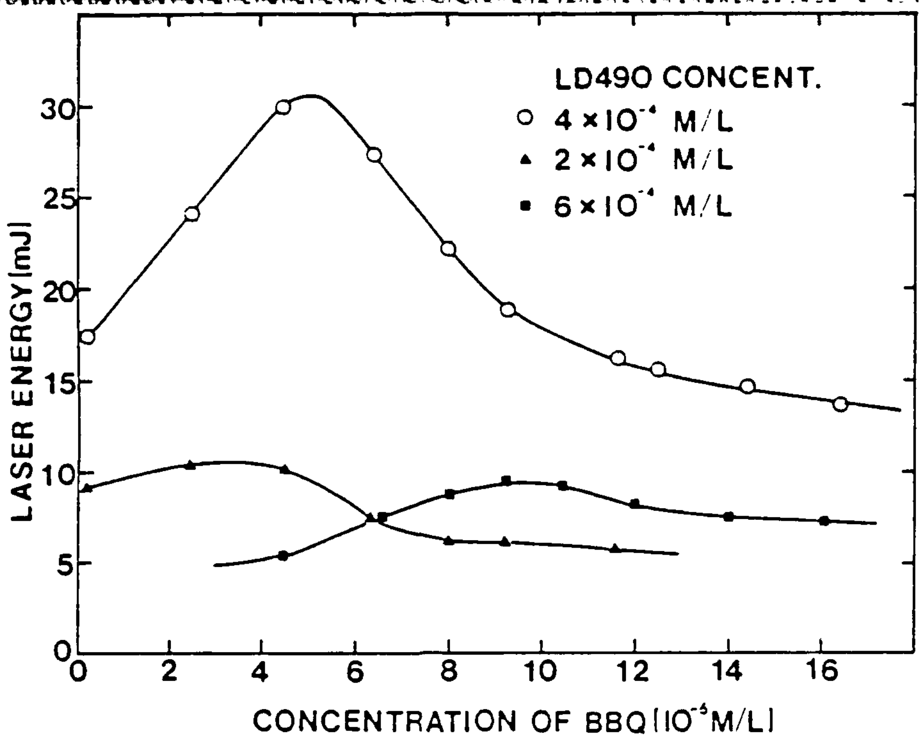


Fig. 6 Blue-green laser output of LD 490 dye as a function of BBQ dye (converter dye).

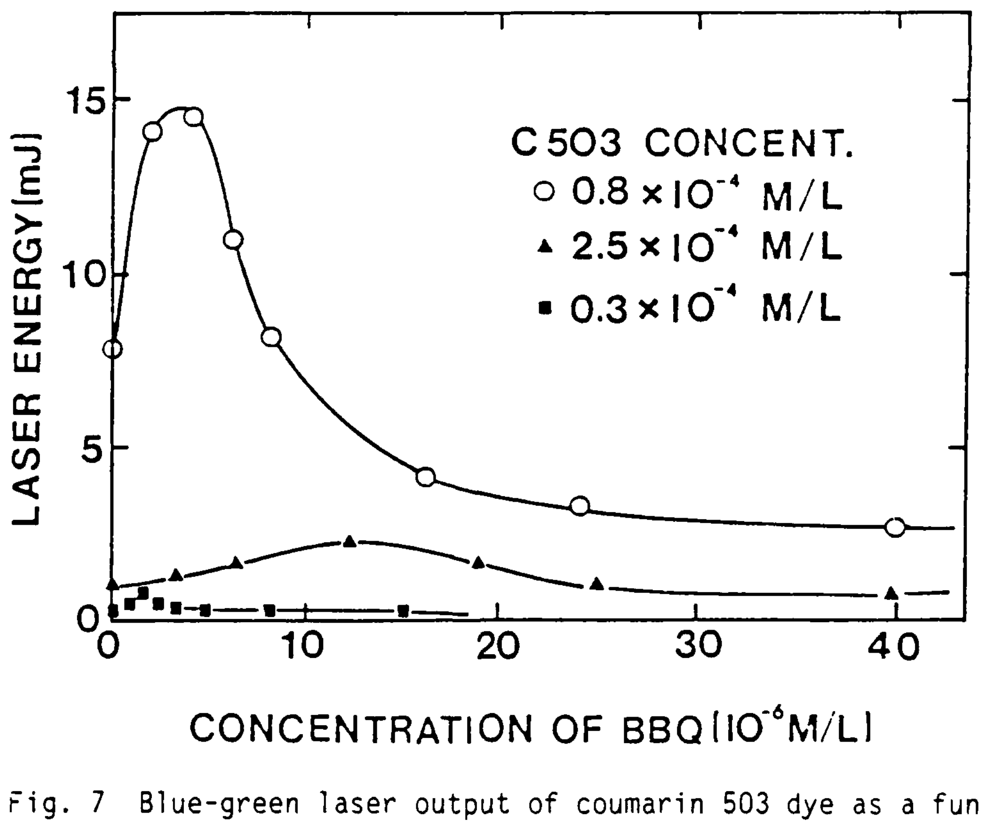


Fig. 7 Blue-green laser output of coumarin 503 dye as a function of BBQ dye (converter dye).

P-Terphenyl DYE Laser

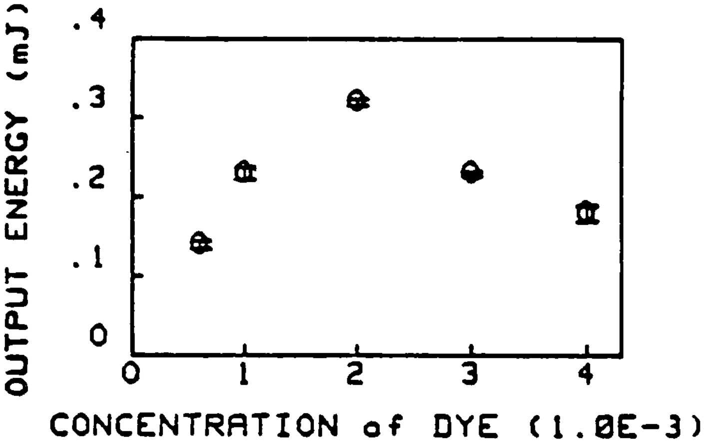


Fig. 8a Gas pressure: 0.75 Torr
Input energy: 530J

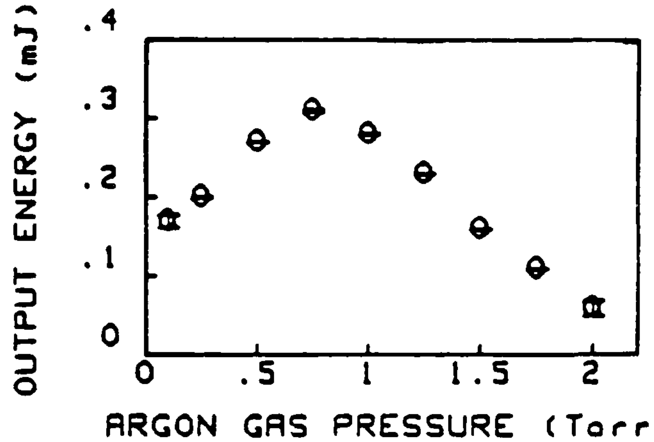


Fig. 8b Concentration : 2×10^{-3} mol/
Input energy : 530J

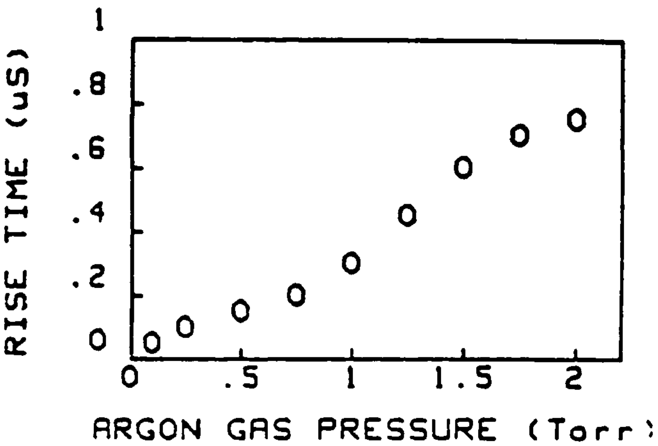


Fig. 8c Input energy: 530J
at 275 nm

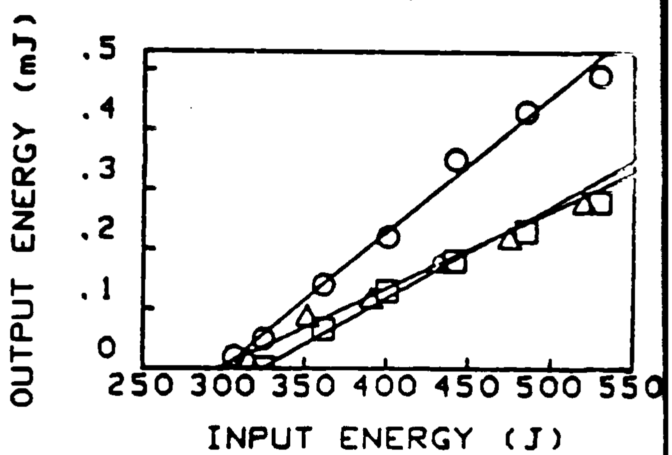


Fig. 8d : 2×10^{-3} mol/liter
: 6×10^{-4} mol/liter
: 4×10^{-3} mol/liter

Fig. 8 P-terphenyl dye laser output (λ_c=337nm) as a function of dye concentration, argon fill gas pressure, and input energy for optimization.
The rise time of the HCP pumping light as a function of argon fill gas pressure

BBQ DYE LASER

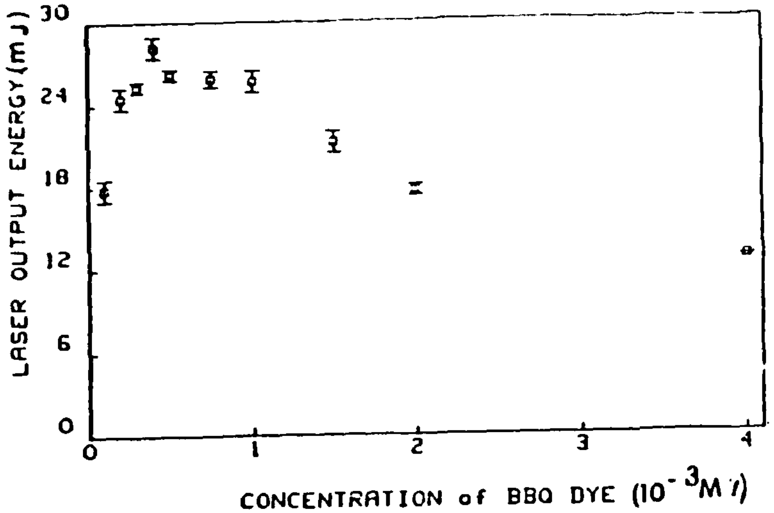


Fig. 9a Argon fill pressure: 2.5 Torr
Input energy : 900J
Transmission of output mirror: 20%

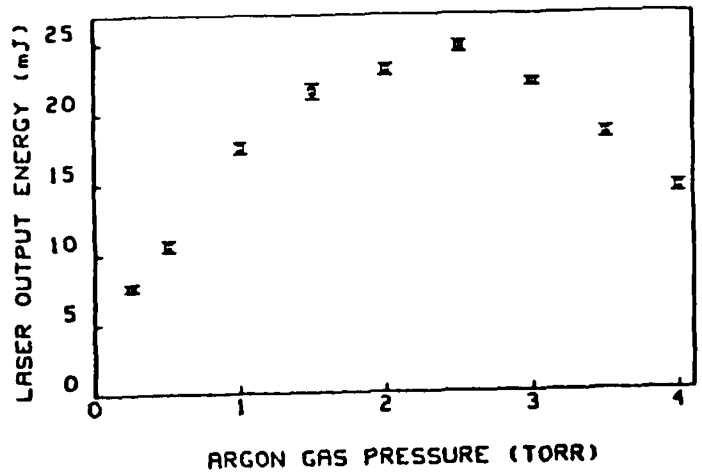


Fig. 9b BBQ dye concentration: $4x10^{-4}$ mol/liter
Input energy : 900J

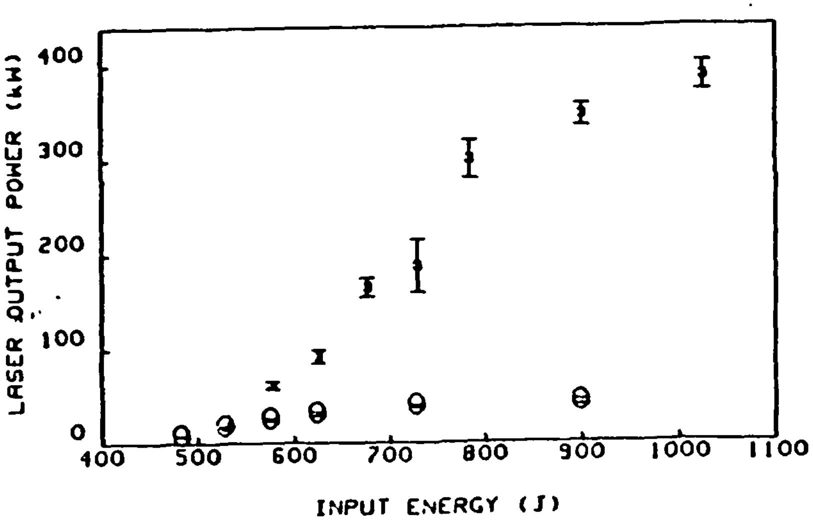


Fig. 9c Argon fill pressure: 2.5Torr
Concentration: $4x10^{-4}$mol/liter
Transmission of output mirror
O: 1%, □: 20%

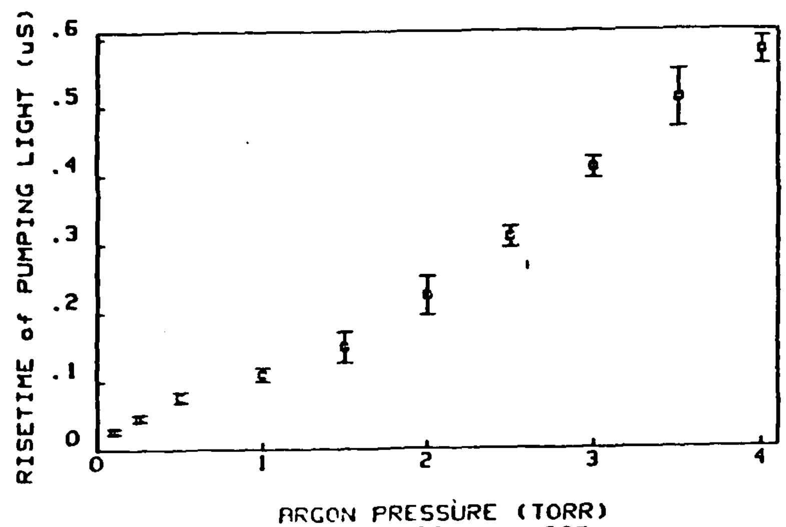


Fig. 9d Input energy: 900J at 307nm

Fig. 9 BBQ dye laser output ($_c$=383nm as a function of dye concentration, argon fill pressure, and input energy for optimization. The rise time of the HCP pumping light as a function of argon fill pressure.

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